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A STUDY OF THE FOOD OF THE MINNOW CAMPOSTOMA ANOMALUM.*

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INTRODUCTION.

Study of the food of minnows is receiving more and more attention, (Breder and Crawford, 1922, p. 287), for the importance of the minnows as food of larger fresh-water fishes, involves the need of getting at the sources of the minnows' nourishment, which must be present in sufficient abundance, if the minnows and consequently the larger fishes are to thrive.

In this paper the food of the minnow Campostoma anomalum is considered. This fish is commonly called the stone-roller, but is also known by such names as stone-lugger, stone-toter, dough belly, rot-gut minnow, greased minnow, greased chub, steel-backed minnow, steel-backed chub, and mammy. It is a common fish in Ohio.

This minnow inhabits small rivers and creeks primarily, is found to great extent in moderate to swift current, and above rocky and pebbly bottom much oftener than above muddy or oftener even than above sandy bottom. It is a fish particularly of the riffles environment.

While the writer was a member of a state fish survey party, (summer of 1920, 1921), working under direction of Prof. R. C. Osburn, for the Ohio Division of Fish and Game, a very great many of this species were taken with the seine. These, as well as some sent by the party in the field in the summer of 1922, were available for the writer's use, and the latter during the same summer, collected many young specimens in the vicinity of Columbus.

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The writer is particularly indebted to Dr. R. C. Osburn, as well as to Mr. E. L. Wickliff and other members of the survey party, and to several other friends and colleagues who helped seine.

For the last two years the writer was engaged in a research on some anatomical features of this interesting species, the results of which work will be published elsewhere. Some 600 specimens were utilized, which had come from a total of 39 Ohio counties, and most were available for food examination. What was thought to be a sufficiently large number, were examined, and all of these are tabulated and discussed below.

PREVIOUS STUDY.

The food of Campostoma has apparently been studied previously in only a few specimens. Forbes, (1883, and reprint, 1912, pp. 69-72), gives the only idea of the nature of the food, and these observations seem to have been used without further investigation later, (Forbes and Richardson, 1908, p. 111).

"Of the great number of specimens available for dissection only nine were studied, since the contents of the intestine were found so uniform in character. * * * The intestine was invariably filled from end to end with a black slimy matter, which, * * * was found to consist almost wholly of fine mud. * * * It (the organic matter) made on an average only about one-fourth of the contents of the intestine, the remainder consisting of finest particles of sand and clay. Not far from one-fifth of the whole amount was of vegetable origin, consisting chiefly of filamentous algæ, mingled with a few diatoms, but comprising occasionally minute fragments of other kinds of vegetation also. The only animal objects noted were occasional Chironomous larvæ and Difflugia. Sometimes the intestine was wholly filled with almost pure mud, in which no organic structures whatever could be detected. Date and locality seemed to make no material difference in the food of this fish, which should evidently be classed as limophagous."

FOOD HABITS OF CAMPOSTOMA.

Campostoma is a bottom feeder for the most part. The head is somewhat sucker-like in general shape, the mouth being ventrally directed, and thus in striking contrast to the more definitely terminal or forwardly directed mouth of many other minnows, such as Notropis, and Semotilus for instance, which are fitted for carnivorous prehension. The lips of Campostoma are fleshy and suggest the sucker lip of not too pronounced type.

Campostoma is particularly adapted to feeding on the diatomaceous and other growths adhering to stones on the bottom of the riffles. The dust fine detritus is no doubt easily ingested, and adhering material appears to be taken about as readily. The writer has observed some Campostoma feeding on stones in a natural habitat, and more extensively in a laboratory aquarium.

There were very few large stones in the aquarium; some of the bottom was covered with pebbles, and a small part was bare. Occasionally a specimen was seen to feed on the bare bottom part, where there was a thin film, probably diatomaceous. More frequently they were probing around among pebbles, very likely feeding. Both algæ and diatoms were thriving there. In the absence of current, the aquarium was entirely unlike their natural habitat. There was no great amount of loose detritus present, in which respect the environment was similar to that of many swift stream bottoms, where the current would remove loose materials. Most of the feeding was witnessed on the sides of the aquarium. For some months, (during which repeated observations were made) the glass walls of the aquarium were covered with a rich plant growth, largely diatomaceous. While this upright position does not seem normal, it seemed to do very well, and certainly presented the richest supply of food. The fish would frequently feed there by coming up against the glass surface, moving along it for a distance of a half inch or so, apparently swallowing as much of the diatomaceous deposit as possible, and then leaving the place for the time being. Short, narrow, cleared spaces, where they had removed the film, could be seen. While a number of artificial conditions existed here, so that the food supply most likely did not prove normal, or adequate, as indicated by the subnormal rate of growth of aquarium fishes, the manner of feeding could be adequately studied in this way.

METHOD OF EXAMINATION OF FOOD.

Because of the long type of intestine, which is small in diameter and coiled, and because of the small size of the particles comprising the intestinal contents, which are generally well packed into this long intestine, the examination of the food of the species is painstaking work. In the adult fishes the intestine is relatively much longer than in the young. It was seen that there was great uniformity along practically all of this length, so that only sections of it were taken, and carefully examined, but these were from near both ends and also middle parts of the canal. Possibly upwards of a third of the total length was examined in all cases. In all young specimens of groups 1 and 2, the entire contents were examined.

The contents, of either an entire canal of a young fish, or of a short section of an older one, were completely spread out over a 3 by 4 inch glass plate, covered with a film of water, and examined with both binocular and compound microscope. The high power (440 diam.) was used for the final examination of all plates. Considerable care was necessary in spreading out the material evenly and widely, so that all portions were clearly distinguishable, and so that estimates of the percentage composition by volume could be made with reasonable degree of fairness. In all cases the determination of what percentage of the total contents any particular kind of food was, rested purely upon an estimate in which a considerable percentage of error was possible, at least where the item concerned was very small in amount and distributed in relatively small sized particles as compared with some other type of food. In all cases the sum of the percentages of foods present is made to equal 100% exactly. It is not to be expected that a figure of 48% or 49%, for an item in some particular fish, represents the quantity of that type of food present, any more accurately than would the figure 50%; the 1%, or 2%, may have been necessary allowance for some small item of food present. There are many instances of small portions in intestinal contents, where the figure 1% seemed just about correct. In some cases such figure might be excessive, but no use of fractional percentage seemed desirable or possible, and the writer wished to obviate the use of the word trace.

THE SPECIMENS STUDIED, WITH TABULATION OF DATA ON INTESTINAL CONTENTS.

Both young and mature specimens were examined for a study of the food of the species. Five groups of 21 specimens were selected, in addition to which there was a small group of lake specimens. Specimens of the five groups have been grouped according to several features, chief of which is size of fish. It is logical to consider generally relation between size of fish, (and hence of its mouth), and size of particles or objects ingested, though where the food consists of such minute objects, this reason may have little or no weight. The specimen number is merely arbitrary, but it happens that, in any collection, numbers were usually assigned according to size of specimens. The arrangement of individuals in a group, where they do not follow a size series, is of no significance.

Group 1, (table 1), consisted of 21 very young Campostoma, including some of the smallest taken in the entire study. Sixteen of these were from a very small creek, tributary to the Olentangy River, north of Worthington, Franklin County. This run averaged only 2 to 3 feet wide, and was a favorable breeding place. These 16 were merely a portion of the collection, taken at one date and one place, all evidently of one school, and probably of the same age. This is a selection showing range in size of specimens of the collection, rather than a selection of all specimens of one size, at an extreme or average of the body length of the fishes. It is notable that specimens which are very likely of one age, show such difference in size so early in life. The variation in length of a large group is a continuous one, with most specimens at about the median point. For groups 2 and 3 a similar selection of range in size was made.

Group 2, (table 2), includes 21 young Campostoma taken entirely from Big Run, a small creek, tributary to the Olentangy River, north of Clintonville, Franklin County. This is somewhat larger than the run west of Worthington. It is also a favorable breeding place. The specimens were collected later in the month than those of table 1, though the different length of the group as a whole compared with group 1, cannot be attributed to a definite difference in age, since one cannot tell whether the eggs hatched at the same time or not in the two places. The last 15 specimens were collected at later date than the first 6, as shown in the table. They belonged to the same general school very likely.

Group 3, (table 3), is likewise a selection of 21 young specimens from Big Run, but collected later in the summer when they were larger.

Group 4, (table 4), includes 21 specimens of a wide distribution, from 21 different streams, although some of these streams are tributary to others represented in the table. With the exception of the north and northwestern parts, all sections of the state are represented. Even a wider distribution might have been made, but for the desire to keep to a certain narrow range in specimen length. The minimum of 50 mm. makes all specimens in the group of greater length than those of preceding tables.

Group 5, (table 5), includes 21 specimens also taken from a wide distribution, but not necessarily from the same places as those of table 4. Somewhat fewer streams are represented, since suitable large specimens were not at hand from others. Many of the largest specimens, and especially practically all those of 100 mm. or greater length, are included here. This selection should be a satisfactory lot for the study of the adult food.

TABLE 1. INTESTINAL CONTENTS OF 21 VERY YOUNG CAMPOSTOMA.

Fish						Types Eaten with Percentages by Volume														
Specimen No.	Date of Collect.	Locality—Stream	Length of Fish	Length of Intest.	Degree Filled	Bacteria	Diatoms	1-Cell Blue-green	1-Cell Green Algae	Filamentous Green	Leaf of Plant	Unrecog. Plant Rem.	Protozoa	Rotifers	Copepoda	Cladocera	Ostracoda	Fly Larvae	Unrecog. Animal Rem.	Inorganic
294	June 3	Run west of Worthington	13	12	½		85			5								10		
300	"	" " "	14	15	¼		30			55										15
301	"	" " "	15	17	¾		15			5				5	40	20	5		5	5
302	"	" " "	15	19	¾	5	75			5				5						10
303	"	" " "	15	19	½	5	50					10		5	10					20
304	"	" " "	15	19	1		35			30				5	10	10				10
322	"	" " "	17	26	1	2	85					3								10
327	"	" " "	17	24	1					80		15								5
335	"	" " "	18	27	1	3	80					5								12
340	"	" " "	18	22	1			3		40				2		50				5
342	"	" " "	19	30	¾			3					2	95						
343	"	" " "	19	24	¾		75	6												16
344	"	" " "	19	27	½	5	15			35	15	15								15
345	"	" " "	19	30	¾		88													12
352	"	" " "	19	27	½	5	10	10		20	20	15		5						15
353	"	" " "	20	26	1		90													10
366	June 9	Scioto—Big Run	18	22	¾	5	15	15				40		10						15
367	"	" "	18	29	¾	1	15	30				40	4							10
371	"	" "	22	35	½	5	65	10				10								10
372	"	" "	22	41	½		90													10
373	"	" "	23	36	1	4	35	25	15			5								16

TABLE 2. INTESTINAL CONTENTS OF 21 YOUNG CAMPOSTOMA.

Fish						Types Eaten with Percentages by Volume										
Specimen No.	Date of Collect.	Locality—Stream	Length of Fish	Length of Intest.	Degree Filled	Bacteria	Diatoms	Desmids	Filamentous Green	Unrecog. Plant Rem.	Cladocera	Setae of Annelida	Midge Larvae	Egg of Insect	Unrecog. Animal Rem.	Inorganic
375	June 14	Big Run, Clintonville	25	65	1		1			9			85			5
379	"	" " "	23	39	¾	7	60	4	7	12						10
380	"	" " "	23	44	1	10	70	3		7						10
382	"	" " "	24	41	½		2			5			90			3
383	"	" " "	24	46	¾	3	80	7								10
386	"	" " "	25	59	1	5	75	6		4						10
388	June 19	" " "	26	54	1	4	80			6						10
389	"	" " "	29	97	1	1	83			4						12
391	"	" " "	24	48	1	1	70	10		4						15
392	"	" " "	24	38	¾		65	3	10	10						12
396	"	" " "	25	63	1	2	70	3	10	4	3					8
400	"	" " "	26	42	1		75	4		6						15
401	"	" " "	26	57	½	5	55	5		20						15
405	"	" " "	27	60	¾	1	60	4	5	10						20
407	"	" " "	28	60	¾	5	60	4	1							30
416	"	" " "	29	73	1	2	55	5		20		3				15
417	"	" " "	28	68	1		65	5		10						20
418	"	" " "	30	74	¾		55	6	5	10		4				20
423	"	" " "	29	64	¾		65	5		10					5	15
424	"	" " "	29	71	1	5	50	5		15						25
427	"	" " "	29	87	1		55	8	6	10				1		20

TABLE 3. INTESTINAL CONTENTS OF 21 YOUNG CAMPOSTOMA.

Fish						Types Eaten with Percentages by Volume.												
Specimen No.	Date of Collect.	Locality—Stream	Length of Fish	Length of Intest.	Degree Filled	Bacteria	Diatoms	1-Cell Blue-green	Filamentous Blue-green	1-Cell Green Algae	Desmids	Filamentous Green	Leaf of Plant (part)	Unrecog. Plant Rem.	Setae of Annelida	Midge Larvae	Egg of Insect	Inorganic
482	July 15	Big Run, Clintonville	37	111	¾		40							30				30
484	“	“ “ “	39	114	¾		50				5	5		10				30
485	“	“ “ “	39	138	1	8	45				2	5		20				20
524	August 5	“ “ “	39	119	¾		30					15		15				40
526	“	“ “ “	39	101	½		30					10		10				50
528	“	“ “ “	42	128	¾	4	30					5		20	1			40
529	“	“ “ “	42	143	1	3	40	1	1			5		20				30
530	“	“ “ “	43	160	¾		40		10			10		15				25
531	“	“ “ “	44	157	1	5	25	1	4			20		15				30
533	“	“ “ “	43	156	¾	1	25	1	8			15		15				35
534	“	“ “ “	42	146	1	3	25	1		1		5		20		5		40
535	“	“ “ “	44	178	1	3	30	2		1	1	5		18				40
536	“	“ “ “	43	191	1	5	25				1	4	10	15				40
537	“	“ “ “	44	192	1	5	25					5		10				55
538	“	“ “ “	45	167	¾	4	20		2			4		10				60
540	“	“ “ “	46	207	1	1	20				1	3		10				65
541	“	“ “ “	47	188	1	1	30				1	5		8				55
542	“	“ “ “	47	196	¾	4	30	1				10		5				50
543	“	“ “ “	48	202	¾	1	40				1	5		8				45
545	“	“ “ “	48	198	1	2	40					4		10			2	42
547	“	“ “ “	49	195	1	1	30	1				3		5				60

TABLE 4. INTESTINAL CONTENTS OF 21 CAMPOSTOMA.

Fish							Types Eaten with Percentages by Volume.										
Specimen No.	Date of Collect.	Locality Collect.—Stream	County	Length of Fish	Length of Intest.	Degree Filled	Bacteria	Diatoms	1-Cell Blue Green	Filament. Blue-Green	1-Cell Green Algae	Filamentous Green	Desmids	Unrecog. Plant Rem.	Protozoa (Euglena)	Unrecog. Animal Rem.	Inorganic
61	June 17	Cold Water Run	Columbiana	52	212	1	1	50		1		2		4			42
66	" 18	N. Fork, Little Beaver	Columbiana	55	245	¾	3	75					1	6			15
73	" 21	Cross Creek	Jefferson	58	355	1	1	5		1				3			90
75	" 29	McMahon's Creek	Belmont	55	275	1	2	8				5	2	3			80
77	" 30	Sugar Creek	Guernsey	56	296	1	1	3				1		15			80
84	July 7	Duck Creek	Noble	58	280	1	1	5		2				22			70
94	" 11	Newell's Creek	Washington	53	222	1	1	1		1		1		10		1	85
101	" 13	Wolf Creek	Washington	50	169	½		1						8	1		90
109	" 14	Hocking River	Athens	54	302	¾	5	15				3		12			65
119	" 19	Indian Guyan Creek	Gallia	51	130	1	1	1		3		35		10			50
127	" 21	Turkey Creek	Scioto	57	315	1	1	48		4		40		2			5
152	Aug. 1	E. Fork, Little Miami	Clermont	57	197	¾	1	7				5	1	6			80
159	" 5	4-Mile Creek	Butler	50	234	1	1	5		1				8			85
177	" 8	Little Miami River	Warren	53	302	1		5		5				10			80
189	" 8	Big Miami River	Warren	51	200	¾	1	4						5			90
205	" 22	Licking River	Muskingum	52	241	1	2	6			1		1	10			80
215	" 25	Walhonding River	Coshocton	56	265	1	1	20				10	1	15			53
227	" 25	Mohican River	Coshocton	56	259	1	1	25				1		13			60
233	" 26	Tuscarawas River	Coshocton	53	212	1	1	20		2				10	2		65
257	Sep. 13	Olentangy River	Franklin	53	250	¾	1	7	1	3				15	3		70
288	May 5	Big Walnut Creek	Franklin	55	225	1	2	60				1		7			30

Fish							Types Eaten with Percentages by Volume												
Specimen No.	Date of Collect.	Locality—Stream	County	Length of Fish	Length of Intest.	Degree Filled	Bacteria	Diatoms	1-Cell Blue-green	Filamentous Blue-green	Desmids	Filamentous Green	Unrecog. Plant Rem.	Protozoa (Euglena)	Setae of Annelida	Egg of Insect	Midge Larvae	Unrecog. Animal Rem.	Inorganic
2	June 20	Hocking River	Fairfield	92	349	½	7	7			1						75		10
5	" 20	Hocking River	Fairfield	90	401	¾	3	35			3	4	10				5		40
10	Aug. 18	Mahoning River	Trumbull	93	507	1	3	25			3	4	10				5		50
42	July 17	Mosquito Creek	Shelby	77	282	½	5	5					15				5		70
46	" 28	Beaver Creek	Mercer	86	655	1	3	5		1	1	1	8			1			80
50	Aug. 26	Deer Creek	Madison	79	416	1	2	35		2	2	4	10						45
70	June 20	M. Fork, Little Beaver	Columbi'na	89	660	1	2	10		8		2	10						68
99	July 12	Wolf Creek	Washington	80	335	½	2	2		5			6						85
170	Aug. 17	Mahoning River	Trumbull	110	614	¾		10		1		3	6						80
202	" 12	Little Miami River	Greene	84	650	1	4	6		15			5						70
212	" 22	Licking River	Muskingum	76	441	1		10		5	5	5	5						70
213	" 23	Jonathon Creek	Muskingum	87	377	½		15					20						55
214	" 23	Walhonding River	Coshocton	86	422	¾	2	10		10		5	20				3		50
243	" 24	Killbuck River	Coshocton	75	283	¾	5	20				10	15						50
244	" 26	Tuscarawas River	Coshocton	88	471	1	8	8				1	7		1				75
256	Sep. 13	Olentangy River	Franklin	83	565	1	1	10	1	10			4	4					70
266	" 13	Big Walnut Creek	Franklin	83	484	1	4	50				1	10						35
281	May 5	Big Walnut Creek	Franklin	87	468	1		85				1	5						9
282	" 5	Big Walnut Creek..........	Franklin	75	386	¾		55		10			5						30
491	July 17	Big Walnut Creek	Franklin	78	287	½	5	15			3	5	15	2				5	50
575	" 3	Tontogany Creek	Wood	84	624	¾	2	15		10		3	10						60

DISCUSSION OF THE FOOD.

In bulk the entire intestinal contents make a compact mass, in many cases quite filling the canal, though occasionally there are parts where it is somewhat loosely placed or where short sections are clear. Only where it was completely filled throughout was it considered filled and marked 1 in the column "Degree filled" in the table. In very few cases examined was it as little as one-half filled. Though of a generally very soft consistency, the contents were hardly "slimy" as Forbes described the mass, except where there was a large mass of filamentous algæ of slimy feel. Examination showed that the soft contents were really very gritty. The color was rarely black, generally some shade of brown, from light to very dark, with more or less of a greenish tinge.

Inorganic matter was seen to be a considerable item in the canal contents. To be sure this was not thought of as food itself, but a prevalent large percentage of it indicates that it is a normal constituent of the canal contents, and evidently something unavoidably taken in, with some mixed organic material, in its method of feeding along the bottom. The inorganic material was found to be of rather uniform nature in all the specimens. The largest portion of it, giving to the whole its gritty consistency, was sand in minute grains or crystals, generally so small as to be scarcely visible individually under the ordinary powers of the binocular, but prominent under the high power of the microscope. There were some much larger grains, but also many smaller than the average, as if ordinary sized grains had been ground up, though there must be very little of such process going on in the alimentary canal of the fish, and very likely great masses of such triturated material exist on the bottom.

A smaller portion of the inorganic constituents comprised softer material, apparently clay, in fine granules, smaller than most of the smallest gritty particles.

In both groups of very young specimens (Tables 1, 2), there was not nearly as much inorganic material present as described by Forbes for this species. The average is about 15%. But even in the next larger group (Table 3), a much larger and somewhat uniform percentage is present. In the adults and other large specimens, (Table 5 and also Table 4) the percentage is high, except in a few specimens. In many it is as Forbes indicates, three-fourths inorganic and one-fourth organic. These percentages are sufficient to indicate that a larger mass of inorganic material is ingested in the more wide-spread feeding of the older fish, and that the relatively small percentage of organic material furnishes enough nutriment which can be absorbed in the long course of the intestine. But in younger fishes, having relatively so short an intestine, inadequate nourishment might result from such a small percentage of organic material. It can hardly be concluded that the young fish selects its food, and that an early selective action is later lost. The contrast, however, between the fairly uniform percentages of the young and those of the old, marks this difference as significant, whatever the cause.

Among the various items of the diet is that referred to as unrecognizable plant remains (Unrecog. Plant rem., as expressed in the table). A careful separation of diatoms and other plant materials from masses of inorganic matter, disclosed some small pieces of green substance in practically all fishes, which seemed to defy all identification. Considerable breaking up from original condition undoubtedly occurred, due probably to grinding up by the gritty inorganic matter, with which it was closely bound up. It was in all cases in this study impossible to say what the source was, whether algæ or some other plant. Varying quantities of distinguishable plant material also were present (as listed in the tables), and of these all the smaller forms (unicellular blue-green algæ and green algæ, as well as the diatoms), were entirely intact. Likewise filaments of short length of both blue-green and green algæ were present. Of the latter numerous, very short and much broken pieces, often only one cell pieces, were found, so that it seems that further trituration of such, by means of the gritty inorganic matter, may account for some of the unrecognizable plant remains. Contents of various plant cells may also give to small masses of inorganic matter, a green tinge. In fact, at first large unrecognizable masses were frequently noted, of somewhat greenish tinge under the light coming through the compound microscope, but it was soon realized that all such had to be laboriously broken up, for masses of elongate diatoms placed criss-cross fashion, together with granules and a little plant substance, made dense masses, which had to be much separated before constituents with percentages for each could be fairly recorded.

Diatoms formed in practically all instances a prominent item of food. In by far the most adult specimens they formed the largest item of organic material, but were overshadowed (except in a few cases) by the inorganic constituents. But it was in the young specimens that diatoms formed such a preponderant part of the entire canal contents. Excluding a few striking exceptions, the diatoms formed in them from half to nine-tenths of the total. In fishes of one locality the diatoms are mostly of just one or a few species. In fishes of groups 1 and 2, coming from three localities, the diatoms were slender elongate species of Navicula, or some species of the very slender genus Nitzschia, with a relatively few of forms like Gomphonema and Tabellaria. No real identifications were attempted in this or other groups of food organisms. Altogether in the food survey here made, at least a dozen kinds of diatoms were present, but never so very many species in one intestine. In the fishes of Table 5, though coming from various localities, there was a preponderance of just a few forms, of which an outstanding type was a somewhat Navicula-like form, short, but bent, possibly Cymbella. In some young specimens, masses of very slender, elongate diatoms were sometimes massed like clumps of needle-like crystals, held by minute quantities of other substances.

Bacteria formed an appreciable percentage in quite a number of fish. Examination showed that, smaller than practically any other particles, and of more regular shape, but not always positively distinguishable from the smallest regular clay or silt-like particles, were some small oval to short rod-shaped forms, that would vibrate with Brownian movement in the dilute food smears on the slides. That they were bacteria there was no doubt, but what their role in the food was, or whether rather intestinal flora than an item of diet, could of course not be determined.

The filamentous green algæ, found in a considerable number of specimens, but in very different proportions, presented quite a variety. Spirogyra was oftenest found, but Mougeotia, Zygnema, Oedogonium, and Vaucheria were also represented in some fish.

In a relatively few specimens among the hundreds of Campostoma collected, there were present large masses of filamentous algæ. None of the specimens studied in detail for food here happened to contain such a large preponderance as did these few striking cases. In these the filaments were very long, instead of broken up, gave a greenish-black color to the entire intestine, made it of softer consistency, and often pierced the weakened walls of the intestine when it was being examined. In these few the filamentous algæ comprised nearly 100%.

The animal food was present in much smaller amounts than the plant food in the specimens examined, but this is due probably merely to the smaller proportion of small animal forms inhabiting stream bottoms.

In a few individuals there was a striking difference from this almost universal rule. Among the 16 specimens from the run west of Worthington, (Table 1), there were five particularly which were unusual in possessing a diet very differently proportioned from the rest, in spite of the fact that they fed in the same locality as all the rest. Moreover these five differed strikingly among themselves. One had ingested 55% filamentous algæ, one 80% filamentous algæ, with an entire absence of diatoms, while the other three had large percentages of animal forms, offering thus a remarkable point of contrast to the others and also to all other Campostoma from any stream examined. One of these contained 50% Cladocera, as well as 40% filamentous algæ, another 40% Copepoda and 20% Cladocera, and the other 95% Rotifers. All of the latter were Anuraea, which in mass produced a delicate pink color, so unlike that of any other Campostoma. The Cladocera present in the specimens just referred to, were mostly Chydorus sphaericus, with a smaller proportion of a species of Daphnia. Of the 21 fish of group 2, there were two which were strikingly different in food ingested. These had consumed almost entirely animal food, midge larvæ in both instances. The reason for such distinct differences and for the individual ingestion of large proportions of some animal food, is not at all evident.

CAMPOSTOMA FROM LAKES.

Campostoma may occasionally be found in lakes. In Illinois, Forbes and Richardson, 1908, p. 99), found it present, (expressing the figures as coefficients of frequency), to the extent of .05 in lakes, as compared with 3.28 in creeks, 2.22 in small rivers, and .21 in large rivers.

TABLE 6. INTESTINAL CONTENTS OF 8 LAKE CAMPOSTOMA.

Fish						Types Eaten with Percentages by Volume									
Specimen No.	Date of Collect.	Locality of Collect. Lake	Length of Fish	Length of Intest.	Degree Filled	Bacteria	Diatoms	1-Cell Blue-green	Filament. Blue-green	1-Cell Green Algae	Desmids	Filament. Green	Unrecog. Plant Rem.	Setae Annelida	Inorganic
45	June 26	Lake St. Mary's	33	111	1	2				15	3	15	30		35
47	Aug. 14	Summit Lake	37	78	½	3	10	1	5				35	1	45
48	" 16	Milton Reservoir	36	109	¾	2	15		18				25		40
249	Sep. 1	Buckeye Lake	36	146	1	4	20			2	2	2	20		50
556	June 30	Nettle Lake	26	95	1	1	55		5			1	10		28
561	" "	" "	30	135	1	1	45	1	3				15		35
564	" "	" "	35	130	¾	1	20	1			1	15	12		50
565	" "	" "	34	160	¾	2	35	2	10		1		10		40

In the present work a relatively very small number were secured from lakes, although fully as much seining proportionately was done in lakes as in streams, so that the scarcity of this species in lakes is demonstrated. All lake specimens at hand were used, (table 6), except a few from Nettle Lake, where a fair number were obtained. The specimens included in the table were thought to be sufficient. In fact, in no case, even in the study of the young creek specimens (tables 1, 2, 3), were all individuals used that were collected.

In lakes the species appears to be restricted to certain few parts where environment compares favorably in at least some important features, with that of streams, where Campostoma is usually found. Of course it is not to be expected that lake specimens are individuals adapted to deep water, or to shoreward marshes, etc. Different lakes would differ much in their likelihood of harboring Campostoma. The five lakes represented are far apart and differ in many details, which are of no import here, except to show that Nettle Lake is evidently more uniformly of a sort suitable for the existence of this fish. It is shallow, clear, and has a sandy bottom throughout. In the case of the other lakes, the Campostoma taken were also from situations near shore where there was similarly a sandy or a somewhat pebbly bottom.

Examination of table 6, and a comparison with all preceding tables, shows no striking general difference between the stream and lake Campostoma. The latter are in part, of similar size as specimens of table 2, although it happens that most are of length between those of tables 2 and 3. If one considers all these more or less comparable specimens, and excludes especially the few very unusual diet individuals from the stream series, very little appreciable difference in diet is noticeable between stream and lake specimens, although one might conclude that there were slightly fewer diatoms, somewhat more algæ, and somewhat more inorganic matter in the lake specimens. Granting that these differences are negligible, it is nevertheless true that there seems to be a larger variety and possibly a larger quantity of algæ. In the diet of a few of the lake specimens were found Pediastrum and one or two other green algæ, absent from stream specimens. These are typical lake forms, though not generally found on the bottom. Their presence, but in such small percent, is then just what one might expect.

This data, though meagre, really shows that there is no particular selection of food organisms, for the lake specimens consumed such food as was present. The diet was similar to that of the majority of stream specimens, merely because the habitats presented in most respects the same general types of food materials. This is a prerequisite. In lake environments differing much from streams in the available food supply, Campostoma would not be found.

The question of the larger differences between the stream fauna and flora and that of the particular lake habitats in which Campostoma was secured, does not enter here. In no case has there been available, detailed, comparable collections of all the organisms of these waters in order to make comparison between existing fauna and flora and that which was ingested.

SUMMARY AND CONCLUSIONS.

Campostoma anomalum, a fish of wide distribution in Ohio, is primarily found in or on riffles in streams.

A study of the intestinal contents of a considerable series of specimens of various sizes and from many streams, seems to allow the following conclusions.

This species of fish is a bottom feeder par excellence, the ventrally directed mouth being applied in removing both loose bottom materials and attached growths. Particles ingested are generally of microscopic size, except that in some instances fairly long filaments of filamentous algæ may be ingested.

A large amount of inorganic material is present in the canal. Often as much as three-fourths of the total is of inorganic nature in the adults. In the young there is a uniformly smaller percentage.

Organic material is present, forming in the adults from less than a fourth to fully a half of the contents, and in the young generally from three-fourths to nine-tenths of the total.

Plants are far more abundant than animals in the diet, there being only trifling amounts of the latter, except in a few exceptional cases where certain animal organisms were taken in large quantity.

Diatoms form the preponderant item of organic nature in the alimentary canal, of both young and adult, except for a few unusual cases. In young fishes diatoms may form from one-half to nine-tenths of the total contents.

The difference between young and adult can hardly be explained on the basis of selection of food, but there is a correlation between the much lower percentage of organic material in the adult and its relatively very long intestine.

The few instances of striking differences in diet of young fishes from that of the rest taken at exactly the same place and time, is not explicable at present.

A few lake specimens showed no notable differences in diet. These specimens were from situations that resembled in some important features, some general stream habitats.

On the whole the diet is such as one might naturally expect in the environment which Campostoma frequents. A general uniformity of diet among large numbers of specimens is not remarkable, considering the uniformity of its habits and habitats.

This minnow is particularly valuable as fish food, because it forms in one step [like the gizzard shad in a different aquatic situation, (Tiffany, 1920, p. 121)], the chain from the very fundamental microscopic food materials, to the game fishes. It ingests directly the abundant, rich bottom debris, living upon diatomaceous and other organic remains. It serves as good food for game fishes. Furthermore it is common and tenacious of life. It must receive important consideration in any future, more intensive fish cultural practice.

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